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Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems —

Part 1:
On-land pipelines

Industries du pétrole et du gaz naturel — Protection cathodique des systèmes de transport par conduites —

Partie 1: Conduites terrestres

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15589-1 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

ISO 15589 consists of the following parts, under the general title *Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems*:

— *Part 1: On-land pipelines*

— *Part 2: Offshore pipelines*

Introduction

Pipeline cathodic protection is achieved by the supply of sufficient direct current to the external pipe surface, so that the steel-to-electrolyte potential is lowered to values at which external corrosion is reduced to an insignificant rate.

Cathodic protection is normally used in combination with a suitable protective coating system to protect the external surfaces of steel pipelines from corrosion.

External corrosion control in general is covered by ISO 13623.

Users of this part of ISO 15589 should be aware that further or differing requirements may be needed for individual applications. This part of ISO 15589 is not intended to inhibit alternative equipment or engineering solutions to be used for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, any variations from this part of ISO 15589 should be identified.

Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems —

Part 1: **On-land pipelines**

1 Scope

This part of ISO 15589 specifies requirements and gives recommendations for the pre-installation surveys, design, materials, equipment, fabrication, installation, commissioning, operation, inspection and maintenance of cathodic protection systems for on-land pipelines, as defined in ISO 13623, for the petroleum and natural gas industries.

This part of ISO 15589 is applicable to buried carbon steel and stainless steel pipelines on land. It can also apply to landfalls of offshore pipeline sections protected by onshore-based cathodic protection installations.

This part of ISO 15589 is also applicable to retrofits, modifications and repairs made to existing pipeline systems.

NOTE Special conditions sometimes exist where cathodic protection is ineffective or only partially effective. Such conditions can include elevated temperatures, disbonded coatings, thermal-insulating coatings, shielding, bacterial attack and unusual contaminants in the electrolyte.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 13847, *Petroleum and natural gas industries — Pipeline transportation systems — Welding of pipelines*

ASTM G 97[1)], *Standard test method for laboratory evaluation of magnesium sacrificial anode test specimens for underground applications*

1) American Society for Testing and Materials, 100 Barr Harbour Drive, West Conshohocken, PA 19428-2959, USA

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 and the following apply.

3.1
anode backfill
material with a low resistivity, which may be moisture-retaining, immediately surrounding a buried anode, for the purpose of decreasing the effective resistance between the anode and the electrolyte and to prevent anode polarization

3.2
bond
metal conductor, usually copper, connecting two points on the same or on different structures, usually with the intention of providing electrical continuity between the points

3.3
cathodic protection system
system consisting of a d.c. current source and an anode in order to provide protective current to a metallic structure

3.4
coupon
representative metal sample of known surface area used to quantify the extent of corrosion or the effectiveness of applied cathodic protection

3.5
d.c. decoupling device
protective device that conducts electricity when predetermined threshold voltage levels are exceeded

EXAMPLE Polarization cells, spark gaps and diode assemblies.

3.6
drain point
location of the negative cable connection to the protected structure through which the protective current returns to its source

3.7
galvanic anode
electrode that provides current for cathodic protection by means of galvanic action

3.8
groundbed
system of buried or immersed galvanic or impressed-current anodes

3.9
impressed-current anode
electrode that provides current for cathodic protection by means of impressed current

3.10
impressed-current station
station containing the equipment which provides cathodic protection by means of impressed current

3.11
impressed-current system
system which provides cathodic protection by means of impressed current

3.12
instant-on potential
structure-to-electrolyte potential measured immediately after turning on all sources of applied cathodic protection current

3.13
intensive measurement technique
technique which simultaneously measures pipe-to-electrolyte potentials and associated perpendicular potential gradients

NOTE The intensive measurement technique identifies coating defects and enables calculation of IR-free potentials at the defects.

3.14
IR drop
voltage, due to any current, developed between two points in the metallic path or in the lateral gradient in an electrolyte such as the soil, measured between a reference electrode and the metal of the pipe, in accordance with Ohm's Law

3.15
IR-free potential
polarized potential
structure-to-electrolyte potential measured without the voltage error caused by the IR drop from the protection current or any other current

3.16
isolating joint
electrically-insulating component inserted between two lengths of pipe to prevent electrical continuity between them

EXAMPLE Monobloc isolating joint, isolating flange, isolating coupling.

3.17
monitoring station
test post
station where measuring and test facilities for the buried pipeline are located

3.18
on-potential
structure-to-soil potential measured while the cathodic protection system is continuously operating

3.19
off potential
instant-off potential
structure-to-electrolyte potential measured immediately after interruption off all sources of applied cathodic protection current

NOTE This potential is normally measured immediately after the cathodic protection system is switched off and the applied electrical current stops flowing to the bare steel surface, but before polarization has decreased.

3.20
protection potential
structure-to-electrolyte potential for which the metal corrosion rate is insignificant

3.21
reference electrode
electrode whose open circuit potential is constant under similar conditions of measurement, used to measure the structure-to-electrolyte potential

3.22
remote earth
that part of the electrolyte in which no measurable voltages, caused by current flow, occur between any two points

NOTE This condition generally prevails outside the zone of influence of an earth electrode, an earthing system, an impressed-current groundbed or a protected structure.

3.23
stray current
current in the path other than the protective current under consideration

4 Symbols and abbreviations

a.c. alternating current

CP cathodic protection

CSE copper–copper sulfate (saturated) reference electrode

d.c. direct current

SCC stress corrosion cracking

SCE calomel reference electrode

5 Design requirements

5.1 General

For new construction projects, the design of the CP system shall be part of the total pipeline design and corrosion management. The details of the pipeline isolation (e.g. location of isolating joints) and the protective coating system shall be included.

Design, fabrication, installation, operation and maintenance of CP systems shall be carried out by experienced and qualified personnel.

5.2 Design information

The following technical information shall be collected and considered when designing a CP system:

— detailed information on the pipeline to be protected, e.g. length, diameter, wall thickness, type and grade of material, protective coating, operating temperature profile, design pressure;

— products to be transported;

— the required design life of the CP system;

— relevant drawings of the pipeline route, showing existing CP systems, existing foreign structures/pipelines etc.;

— environmental operating conditions for the CP equipment;

— topographical details and soil conditions, including soil resistivity;

- climatic conditions, e.g. frozen soil;
- the possibility of telluric current activity;
- location, route and rating of high-voltage overhead or buried power lines;
- valves and regulating station locations;
- water, railway and road crossings;
- casing pipes that will remain after construction;
- types of pipeline bedding material;
- types and locations of isolating joints;
- characteristics of neighbouring a.c. and d.c. traction systems (e.g. electrical substations and their operating voltages and polarities) and other interference-current sources;
- types and locations of earthing systems;
- availability of power supply.

The following information should be considered in the design of the pipeline CP system:

- soil pH, and the presence of bacteria which can cause corrosion;

- types and locations of neighbouring telemetry systems which can be used for remote monitoring.

5.3 Criteria for CP

5.3.1 General

The metal-to-electrolyte potential at which the corrosion rate is less than 0,01 mm per year is the protection potential, E_p. This corrosion rate is sufficiently low so that corrosion will be within acceptable limits for the design life. The criterion for CP is therefore

$$E \leqslant E_p$$

The protection potential of a metal depends on the corrosive environment (electrolyte) and on the type of metal used.

The protection potential criterion applies at the metal/electrolyte interface, i.e. a potential which is free from the IR drop in the corrosive environment (IR-free potential/polarized potential).

Some metals can be subject to hydrogen embrittlement at very negative potentials, and coating damage can also increase at very negative potentials. For such metals, the potential shall not be more negative than a limiting critical potential E_l. In such cases, the criterion for CP is

$$E_l \leqslant E \leqslant E_p$$

5.3.2 Protection criteria

5.3.2.1 The CP system shall be capable of polarizing all parts of the buried pipeline to potentials more negative than −850 mV referred to CSE, and to maintain such potentials throughout the design life of the pipeline. These potentials are those which exist at the metal-to-environment interface, i.e. the polarized potentials.

To prevent damage to the coating, the limiting critical potential should not be more negative than −1 200 mV referred to CSE, to avoid the detrimental effects of hydrogen production and/or a high pH at the metal surface.

For high strength steels (specified minimum yield strength greater than 550 MPa) and corrosion-resistant alloys such as martensitic and duplex stainless steels, the limiting critical potential shall be determined with respect to the detrimental effects in the material due to hydrogen formation at the metal surface. Stainless steels and other corrosion-resistant alloys generally need protection potentials more positive than −850 mV referred to CSE; however, for most practical applications this value can be used.

For pipelines operating in anaerobic soils and where there are known, or suspected, significant quantities of sulfate-reducing bacteria (SRB) and/or other bacteria having detrimental effects on pipeline steels, potentials more negative than −950 mV referred to CSE should be used to control external corrosion.

For pipelines operating in soils with very high resistivity, a protection potential more positive than −850 mV referred to CSE may be considered, e.g. as follows:

— −750 mV for $100 < \rho < 1\,000$;

— −650 mV for $\rho \geqslant 1\,000$

where ρ is the soil resistivity, expressed in ohm metres.

As an alternative to the protection potentials given above, a minimum of 100 mV of cathodic polarization between the pipeline surface and a reference electrode contacting the electrolyte may be used. The formation or decay of polarization shall be measured in accordance with A.2.3.

5.3.2.2 The application of the 100 mV polarization criterion shall be avoided at higher operating temperatures, in SRB-containing soils, or with interference currents, equalizing currents and telluric currents. The conditions should be characterized prior to using this criterion. Furthermore, the criteria shall not be used in case of pipelines connected to or consisting of mixed metal components

5.3.2.3 Under certain conditions, pipelines suffer from high-pH SCC in the potential range −650 mV to −750 mV, and this shall be considered when using protective potentials more positive than −850 mV.

5.3.2.4 Care should be exercised in the use of all protection criteria where the pipeline is electrically continuous with components manufactured from metals more noble than carbon steel, such as copper earthing systems.

5.3.2.5 For pipelines operating at temperatures above 40 °C, the above values may not provide adequate protection potential. In these cases, alternative criteria shall be verified and applied.

5.3.3 Measurements of protection potentials

Measurement techniques shall be in accordance with Annex A.

Other practical reference electrodes to CSE may be used for the various criteria provided that their properties are reliable and documented.

If a.c. interference is present on a pipeline, a.c. corrosion can occur even though the protection potential is achieved (see Annex B).

5.4 Predesign investigations

A site survey shall be carried out before preparing the pipeline CP design. Information obtained during previous site surveys relevant to the proposed pipeline route may be used provided that the date and source of such surveys are documented. If the area to be surveyed is affected by seasonal changes, these shall be taken into account and the most severe conditions with respect to the soil conditions shall be used for the design.

The survey report shall contain the design information specified in 5.2.

Representative soil resistivity values should be obtained at pipeline depth along the route of the pipeline, and shall be obtained at various depths at prospective locations for anode groundbeds. The number of measurements should be based on local soil conditions. If there are changes in soil characteristics, more measurements shall be taken.

If corrosive conditions are anticipated due to bacterial activity, appropriate action shall be taken which might include chemical and bacterial analyses of the soil. This requirement shall be extended to the imported soil used for pipeline trench construction.

Possible sources of detrimental d.c. and a.c. interference currents shall be investigated, and the design shall include measures to mitigate the effect of such currents. Annex B shall apply with respect to the detection and control of interference currents.

Locations where high-voltage a.c. transmission lines or a.c.-powered train systems cross, or run parallel to, the pipeline shall be identified.

5.5 Electrical isolation

Isolating joints should be installed above ground whenever possible at both extremities of a pipeline, and should also be considered at the following locations:

— at connections to branch lines;

— between pipeline sections with different external coating systems;

— between pipeline sections running in different types of electrolyte (e.g. at river crossings);

— in areas of high telluric activity;

— on pipeline sections which are differently affected by a.c. or d.c. interference currents;

— between cathodically-protected pipelines and non-protected facilities.

Monobloc isolating joints should be used wherever possible. Each isolating joint/isolating flange should be provided with test facilities.

Safety-earthing and instrument-earthing shall be mutually compatible with the CP system. In areas where there could be an unacceptable risk of high voltages on the pipeline exceeding the joint's electrical capacity, e.g. caused by nearby power systems or lightning, the isolating joints or flanges shall be protected using electrical earthing or surge arrestors.

The design, materials, dimensions and construction of the isolating joints shall meet the design requirements of ISO 13623.

If the pipeline is transporting any fluids that are electrically conductive, the isolating joints shall be internally coated on the cathodic (most expected negative potential) side, for a length sufficient to avoid interference-current corrosion. All sealing, coating and insulation materials shall be resistant to the fluid transported.

The electrical resistance across isolating joints should be more than 10 MΩ measured at 1 000 V (d.c.) in dry air, before installation.

If the use of monobloc isolating joints is not practical, electrical isolation should be provided using isolating flange kits. Isolating flanges should be protected against ingress of dirt and moisture by the use of flange protectors or protective tape.